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# Modeling risk perception in ATIS context through Fuzzy Logic

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**Abstract**

This research is aimed at investigating the effect of accuracy of ATIS (Advanced Traveller Information Systems) in terms of route choices and travellers' concordance to informative system. A Stated Preference Experiment has been made by using a Travel Simulator developed at the Technische Universiteit of Delft (The Netherlands). During the experiment respondents have been asked to make repeated route choices in presence of ATIS. Two kinds of information have been tested: descriptive (respondents are provided with the estimated travel times on each route), and prescriptive (respondents are provided with the estimated shortest route). For each kind of information four levels of accuracy have been considered: high, low and two intermediate levels. The main research aims are: 1. investigating the relationship between accuracy of information and travellers' concordance to informative system; 2. investigating the relationship between accuracy of information and route choices. Some preliminary aggregate and statistical analyses have been made; additionally, collected data have been deeply analyzed, and a fuzzy logic approach has been applied in order to reproduce the travellers' behaviour.

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*Keywords:* Travellers' behaviour; Travel simulator; Stated Preference; Route choice; ATIS; Concordance; Accuracy; Uncertainty; Risk perception; Fuzzy Logic

## 1. Introduction

Information systems are aimed to provide information on traffic conditions so that travellers can make their decisions with less uncertainty. In a context without information, travellers are mainly influenced by their previous experiences. In presence of information, travellers' choices depend on both their experiences and provided information. According to the relevant technical literature, travellers' reaction to information can be modeled in terms of compliance. Travellers can be considered compliant when they choose the route suggested by the informative system, not compliant otherwise. On the other hand, ATIS is accurate when the discrepancy between estimated and actual travel times can be considered not significant. Furthermore, we could expect that compliance is strictly related to the accuracy of informative system (Srinivasan and Mahmassani, 2002). Therefore, the higher the accuracy, the higher the compliance, and travellers tend to choose the suggested route, or that one having the

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shortest estimated travel time. When the accuracy is low, travellers do not trust in the provided information, and usually make their choices on the basis of their personal experience. Several researchers have analyzed the effect of the information accuracy related to the reliability of an alternative route (see, for example, Ben-Elia et al. 2010). In other words, in case of accurate information, respondents' choices are expected to be concentrated on the shortest route, which is also the most suggested by an accurate ATIS. Instead, in case of inaccurate information, uncertainty induces respondents to choose the most reliable route, that usually is also the one having the lowest travel time variance.

More precisely, in this paper we distinguish between the compliance and the concordance. A compliant traveller chooses the suggested route; instead, a concordant traveller not only trusts in (i.e. is compliant to) the informative system, but also he/she would choose the same route on the basis of his/her own considerations. Due to definitions of compliance and concordance, we observe that a traveller compliant to ATIS is always concordant to it; that is, the set of compliant travellers is a subset of the set of concordant travellers. Furthermore, concordance is an upper bound for compliance. Thus, we propose to refer to concordance instead of compliance.

In this paper, the values of travel time have been calculated from the raw experimental data through statistical tools, and then used as input for a Fuzzy Inference System, modelled through triangular membership functions. The output has been computed through a set of fuzzy rules, defining the overall travellers' behaviour, and then "defuzzified" to obtain the route preference. In this way, it is possible to model the uncertainty embedded both in human reasoning and in information data, and evaluate the impact of the informative system on travellers' choices.

The paper is structured as follows. In section 2, a literature review is briefly described. In section 3, an experiment, carried out to collect data by using a Travel Simulator (Hoogendoorn, 2004), has been described. Results of the experiment and their aggregate analysis are shown and discussed in section 4. In section 5 a model based on a fuzzy logic approach is presented. In section 6 conclusions and future perspectives are briefly discussed.

## 2. Literature review

Several researchers have investigated and modelled travellers' behaviour in terms of route choice by making Stated Preference experiments, in which respondents repeatedly make their simulated travel choices (see, for example, Abdel-Aty et al., 1997). In particular, two different conditions of choice can be distinguished: a context without and a context with information. In the first case, respondents make their choices on the base of their previous experiences; in the second case, they are influenced also by the provided information and both quality (Dell'Orco and Teodorovic, 2009; Dell'Orco and Marinelli, 2009; Di Pace and Bifulco, 2010) and accuracy (Shen-Te Chen et al., 1999; Bifulco et al., 2009) of ATIS. The data collected during the experiments have been then interpreted by means of different modelling paradigms. Different approaches to the system dynamics are possible: cross sectional, in which utility values are not dependent on time (Bogers et al., 2007); weighted models, in which attributes of the current utility are modelled as a function of previous weighted values (Horowitz,1984); explicit dynamic models, based on the previous day's experience, like the myopic adjustment approach by Mahmassani and Chang (1986), or the adaptive expectation approach by Cascetta and Cantarella (1991; 1993), in which the current utility is updated by considering both the utility value at previous day and experienced values of attributes.

In terms of discrete choice modelling, the uncertainty effect has also been studied by Ben-Elia and Shiftan (2008; 2010). The relationship between information accuracy and reliability of route actual travel times has been also analyzed by Ben-Elia et al. (2010).

Another relevant aspect in interpreting behavioural data concerns modelling choice paradigm. Although the most adopted approaches so far are generally based on the discrete choice theory, some alternative approaches have been proposed; different attitudes of decision makers have been explained by focusing on the inadequacy of the utility maximization paradigm. In other words, the assumption that travellers make their choices in a perfect rational way could be considered unrealistic in case of an uncertain choice set. First Kahneman and Tversky (1979) have studied through the Prospect Theory the strategies in decision-making under risk and uncertainty. Afterwards, Avineri and Prashker (2005) have used the Prospect Theory to analyze the unreliability/uncertainty effects on travellers' behaviour. They have shown that, in case of high payoff variability, travellers' behaviour tends to move toward random choices; uncertainty of travel times also increases the travellers' inability to perceive the actual differences among the travel times.

An important study about the travellers' attitude toward risk-taking was carried out by Kastikopoulos et al. (2002); it was concerned in quantifying the probability of diversion from the reference route in relation to attitudes toward risk-taking and the expected travel times.

Other alternative approaches, based on Fuzzy Logic (Zadeh, 1965), and Fuzzy Inference (Mamdani and Assilian, 1975; Takagi and Sugeno, 1985) have been introduced in Transportation Engineering (see for example Teodorovic and Kikuchi, 1990; Teodorovic, 1999). Applications of Possibility Theory have been carried out to study drivers' response to information through Approximate Reasoning (Koutsopoulos and Lotan, 1993; Dell'Orco and Teodorovic, 2009), or choice models in transportation (Dell'Orco and Kikuchi, 2004; Kikuchi and Chakroborty, 2006; Murat and Uludag, 2008; Park and Bell, 2011). An extensive discussion of such approaches can be found in Henn (2005). Afterwards, Henn and Ottomanelli (2006) have studied the effect of uncertainty upon traffic assignment by using the Possibility Theory in route choice modelling. Finally, Dell'Orco and Marinelli (2009) have studied the effect of information on travellers' compliance by using the Fuzzy Data Fusion and the Uncertainty Theory.

## 3. Experiment set up

The Stated Preference experiment has been carried out by using an internet based tool, the TSL (Travel Simulator Laboratory - Hoogendoorn, 2004). Connecting to the experiment site, respondents could choose among three alternative routes, and this for 40 consecutive times, in order to simulate 40 successive days. A panel of 160 travellers has been requested to participate to the experiment; 40% of the sample was made of students at a Master School level, 30% were PhD students, researchers and freelancers, 30% were employees. For all scenarios, the travel times that respondents would actually experiment during the simulation changed randomly over days. Instances over days of the actual travel times were the same for all scenarios.

Eight different scenarios have been designed, divided in two sets according to the kind of provided information: scenarios 1 to 4 for descriptive information, scenarios 5 to 8 for prescriptive information. In both sets, the scenarios were ordered on the basis of decreasing accuracy of information. Information itself changed over days to be more precise in case of descriptive information, could be affected by an error with respect to actual travel times (accuracy of information can be identified with the ability of information system in making the accurate estimation of the actual travel times); or, in case of prescriptive information, the suggested routes may be not actually the best ones (in this case information can be considered reliable if the suggested route is the actual shortest one).

At each simulated day, the respondent were asked to choose his/her departure time in order to arrive on time at destination for a job meeting at nine 'o clock (Bonsall, 1997); when the respondent arrived at a diversion node of the network, he/she was asked to choose one among three alternative routes. Such a choice was assisted by a VMS (Variable Message Sign), which could provide the respondents with descriptive or prescriptive information. At the end of the simulated trip, the respondent was notified by the simulator about the actual travel times occurred on all travel alternatives.

All scenarios were the same with respect to actual travel times, and differed from each other only in the level of ATIS accuracy; this means that all respondents of the same scenario (20 respondents per scenario) were exactly in the same travel choice context, and each of these contexts was evolving over time exactly in the same way, even if scenarios were different in terms of provided information. Statistical distributions over time of actual travel times of different routes have been considered independent (see Table 1).

Starting from the hypothesized random distributions of actual travel times, 40 draws have been realized for each route; the resulting sample means and standard deviations are reported in following Table 2. It can be noted that route 1 is on average the shortest, but its travel time can in a few cases drastically increase; route 2 is the worst, but is very reliable; route 3 is intermediate both in terms of average travel time and reliability.

Table 1: Scenarios of the experiment

| Scenario ID | Accuracy Level | Type of Information |
|---|---|---|
| 1 | High | Descriptive (estimated travel times) |
| 2 | Intermediate 1 | |
| 3 | Intermediate 2 | |
| 4 | Low | |
| 5 | High | Prescriptive (estimated shortest route) |
| 6 | Intermediate 1 | |
| 7 | Intermediate 2 | |
| 8 | Low | |

Table 2: Sample means and standard deviations of routes' actual travel times

| Route | Mean (min) | Stand. Dev. (min) | Coeff. of Variation (CV) |
|---|---|---|---|
| 1 | 44 | 15.1 | 0.3411 |
| 2 | 53 | 0.8 | 0.0015 |
| 3 | 47 | 11.9 | 0.2360 |

For the four considered levels of accuracy, we have assumed that ATIS estimates of route travel times were affected by an error with respect to actual travel times. As the error increases, so the (in)accuracy level of the scenario increases from 1 to 4. For each accuracy level, the ATIS error has been considered to be independently distributed across the routes and over days. The distribution is normal for the first three accuracy levels; to avoid abnormal errors, we have chosen a uniform distribution for the last level. In this case, error is such that the resulting instances of ATIS travel time estimates are between 70% of the minimum actual travel time and 130% of the maximum actual travel time, where minimum and maximum are computed over all routes and over all days. Means and standard deviations of ATIS errors for the normally distributed accuracy levels are reported in the following Table 3. For accuracy levels 1 and 2, the standard deviation of the ATIS error for a generic route j is computed with reference to the coefficient of variation of the actual travel time of such a route (CVj – see Table 3). For accuracy level 3, the standard deviation of the ATIS error is not dependent on the actual travel time distributions.

In terms of inaccuracy, descriptive scenarios 1, 2, 3 and 4 respectively correspond to prescriptive scenarios 5, 6, 7 and 8, provided that they refer to a consistent way of designing information and to the same levels of accuracy. In fact, in case of descriptive information, estimated travel time is generated on the base of the accuracy of information; in case of prescriptive information, respondents are provided with the estimated shortest route. In this last case, the shortest route is computed on the base of the estimated travel times of descriptive information scenario at the same accuracy level of prescriptive information.

Table 3: Sample means and standard deviations of ATIS errors

| Inaccuracy Level | Mean | Std. Dev. |
|---|---|---|
| 1 | 0 | 0.25 CVj $\forall$ j∈{1,2,3} |
| 2 | 0 | 0.70 CVj $\forall$ j∈{1,2,3} |
| 3 | 0 | 0.25 $\forall$ j∈{1,2,3} |

With reference to the prescriptive information, on the base of the error made by informative system, ATIS reliability is computed at each trial: it is equal to 1 if the suggestion is congruent with the actual travel times, 0 otherwise. Consequently at first level of accuracy, informative system is reliable with ratio 37/40 over all trial; at second level of accuracy it is reliable with ratio 28/40, at third level of accuracy with ratio 24/40 and at fourth level of accuracy with ratio 13/40.

## 4. Aggregate results

In order to quantify the effect of information accuracy on travellers' behaviour, concordance and route shares have been first evaluated by applying some aggregate (Table 4) and statistical analysis (Table 5).

In Table 4, with reference to each scenario, the aggregate value of the concordance and route share are shown.

Table 4: Frequency distributions of the concordance and route share

| Scenario ID | Concordance % | share of choices | | |
|---|---|---|---|---|
| | | Route 1 % | Route2 % | Route 3 % |
| 1 | 69.0 | 49.2 | 25.0 | 25.8 |
| 2 | 60.8 | 44.3 | 29.6 | 26.1 |
| 3 | 53.4 | 39.8 | 30.2 | 30.0 |
| 4 | 47.9 | 38.9 | 39.1 | 22.0 |
| 5 | 68.0 | 50.8 | 24.1 | 25.1 |
| 6 | 66.2 | 42.9 | 25.5 | 31.6 |
| 7 | 57.3 | 41.4 | 28.9 | 29.7 |
| 8 | 42.3 | 28.7 | 54.2 | 17.1 |

Furthermore, we can make some observations with reference to Table 4. First of all, information accuracy and concordance are strictly related, as expected: if accuracy increases (decreases) concordance increases (decreases). Moreover, route preferences change on the base of the uncertainty perceived by respondents: at high accuracy level, the most chosen route is the most suggested one, which is also the shortest one (Route 1). In case of low level of accuracy, respondents prefer the most reliable route than the shortest one, possibly due to a more uncertain context of choice. More precisely:

- in case of accurate information:
  - the concordance is higher;
  - the most suggested route is the shortest one (Route 1 in this case);
  - the shortest route is also the most chosen one;
- in case of intermediate level of accuracy, share of choices seems to be not significantly different;
- at low accuracy level:
  - in case of descriptive information, the tendency to choose the most reliable route increases (39.1%), and becomes comparable to the tendency to choose the shortest one (38.9%);
  - in case of prescriptive information, the most reliable route becomes the most chosen one (54.2%).

In order to support these preliminary aggregate results, some not parametric test have been made (Table 5). In particular, a Kruskall-Wallis test has been applied for the evaluation of difference between group with reference to route share and travellers' concordance.

In all cases, accuracy can have a non-casual effect if the null-hypotheses can be rejected. A low value, say less than 0.05, of asymptotic significance (*p-value*) allows assessing that information accuracy has a non-casual effect. Table 5 shows that the information effect can be considered significant in all cases, except in case of prescriptive information, comparing scenario 6 to scenario 7 (*p-value = 0.859*).

Table 5: Asymptotic significance (p-values) results of Kruskall Wallis test for the evaluation of the accuracy of information effect on concordance and route share

| Comparison | Choice | | | Concordance |
|---|---|---|---|---|
| | Route1 | Route2 | Route3 | |
| 1-2-3-4 | 0.051 | 0.007 | 0.012 | 0.000 |
| 1-2 | 0.076 | 0.058 | 0.987 | 0.005 |
| 1-3 | 0.011 | 0.475 | 0.035 | 0.000 |
| 1-4 | 0.043 | 0.001 | 0.224 | 0.000 |
| 2-3 | 0.466 | 0.245 | 0.044 | 0.070 |
| 2-4 | 0.810 | 0.193 | 0.233 | 0.000 |
| 3-4 | 0.627 | 0.013 | 0.001 | 0.027 |
| 5-6-7-8 | 0.000 | 0.000 | 0.000 | 0.000 |
| 5-6 | 0.001 | 0.000 | 0.873 | 0.008 |
| 5-7 | 0.277 | 0.421 | 0.667 | 0.008 |
| 5-8 | 0.000 | 0.000 | 0.000 | 0.000 |
| 6-7 | 0.041 | 0.007 | 0.587 | 0.859 |
| 6-8 | 0.008 | 0.000 | 0.000 | 0.000 |
| 7-8 | 0.000 | 0.000 | 0.000 | 0.000 |

The most significant effect of information accuracy, with reference to the route share, can be appreciate comparing scenario 1 (scenario 5) to scenario 4 (scenario 8).

Furthermore, the effect of information accuracy in terms of concordance and route preference seems to be more significant in case of prescriptive information than descriptive information. In fact, concordance in scenario 8 is lower than in scenario 4 (42.3 % vs. 47.9%), and discrepancy between scenario 7 and 8 (57.3% vs. 42.3%) is greater than that one between scenarios 3 and 4 (53.4% vs. 47.9%). Additionally, in case of scenario 8, the preference of route 2 in terms of route percentage (38.5%) is higher than scenario 4 (54.2%).

Thus, we can conclude that, in both cases, intermediate levels of accuracy induce a confused reaction of the respondents, while high level of accuracy induces a better perception of the network performances, and a high level of concordance. Finally, at low accuracy levels and under prescriptive information, the perceived degree of uncertainty is high, and respondents show risk aversion attitude in making route choice.

## 5. Modeling by Fuzzy Logic

Preliminary analyses have shown the effect of information accuracy in terms of route choices and in terms of concordance. On the base of these results, we have used the Fuzzy Logic approach to model the travellers' behaviour. As described in the following, we have found some relationships between provided information and route actual travel times on the one hand, and travellers' preferences/behaviors on the other hand. By using the fuzzy logic, we have modelled through linguistic variables and rules the uncertain way of reasoning embedded in human mind.

### *5.1. The proposed approach*

We can extract some useful parameters that could influence travellers' choices by elaborating estimated and actual travel times; that is, since travellers choose the fastest route or the most reliable one, they compare information, provided in terms of suggested route/estimated shortest route, with previously experienced travel times. On the base of this comparison, a traveller should be able to roughly evaluate the degree of accuracy of an informative system. Thus, ATIS inaccuracy is another input variable that influences travellers' choices.

The approach we have used here is addressed to model all these features with a single, Mamdani-type, fuzzy inference system, which takes into account the uncertainty related to provided information and drivers' behavior, in order to compute route preference. The input attributes, considered in both cases of descriptive information and prescriptive information, are routes characteristics, in terms of actual travel times and their relevant variances, and errors generated by the informative system. All these attributes are normalized in order to scale domain values in the range [0, 1]. The normalization process is computed with reference to attribute values relevant to last previous days.

In particular, the input attributes considered in case of descriptive information are:

- estimated travel time error (TTE). Difference between actual travel times and estimated travel times, with reference to the previous four days;
- estimated travel time (TT), with reference to the previous four days;
- estimated travel time with respect to other routes (TTC). Estimated travel times of three alternative routes within the current day;
- descriptive inaccuracy of the current scenario (DIS), calculated by applying the Eulerian distance among the actual travel times and the estimated travel times of each route;
- variance of the route actual travel times (TTV), with reference to previous six days.

Using two triangular membership functions that represent low and high values of the relevant attributes, each input is transformed into a fuzzy set. Consequently, the attributes are now expressed in verbal values, say for example "Low" or "High", consistent with the information provided to respondents during the experiment. The output variable is the traveller's route preference (RP), computed through a set of IF-THEN fuzzy rules that have been defined considering the overall travellers' behaviour resulting from collected data. This set is made of 33 fuzzy rules such as these main three:

- IF TT is Low and TTC is Low and DIS is Low and DIS is Low and TTV is Low THEN RP is High;
- IF TT is High and TTC is High and TC is High and DIS is High and TTV is High THEN RP is Low;
- IF DIS is High and TTV is Low THEN RP is High.

The first rule represents the best case, in which we have an accurate information system and, at the same time, the fastest route. The second one represents the worst case, with very inaccurate informative system and the slowest route. The third rule includes cases in which travellers have an inaccurate information system but a reliable route (low actual time variance), so drivers prefer this route to others having a higher uncertainty in travel time. The output is computed through the defuzzification process, using the center of area method.

The input parameters considered in case of prescriptive information take into account: ATIS travel time error in previous days, actual travel times, descriptive inaccuracy, and data variance. For each route, five variables as in the following described, have been considered. All input attributes are normalized as in previous case.

In particular, the input attributes considered in case of prescriptive information are:

- estimated travel time error (TTE). Difference between actual travel times and estimated travel times with reference to the previous four days;
- frequency “is first” (IS1). Frequency with which each route has resulted the shortest over last three days;
- the reliability of information (REL). It is 0 or 1 depending on the reliability of the received suggestion. If the suggested route is the actual shortest one, the reliability is equal to 1, otherwise is 0. Its value is the average reliability over last six days;
- the prescriptive inaccuracy of the current scenario (PIS). Difference between actual travel times of the suggested route and travel time of the actual shortest route; it measures how relevant has been a possible error in choosing the route suggested by the ATIS;
- variance of actual travel times of a route (TTV). Value of variance of actual travel times of a route, with reference to previous six days.

As in case of descriptive information, previously described, input is transformed into a fuzzy set using two triangular membership functions, representing low and high values. The output variable is the traveller’s route preference (RP), which is computed through a set of IF-THEN fuzzy rules, defined considering the overall travellers’ behaviour resulting from collected data. This set is made of 33 fuzzy rules such as these main three:

- IF TTE is High and IS1 is Low and REL is Low and PIS is High and TTV is High THEN RP is Low;
- IF TTE is Low and IS1 is High and REL is High and PIS is Low and TTV is Low THEN RP is High;
- REL is Low and TTV is Low THEN RP is High.

The first rule represents the worst case, in which travellers have inaccurate information and, at the same time, the slowest and unreliable route. The second rule represents the best case, with an accurate information system, and the fastest and reliable route. The third rule, like in the descriptive case above, includes cases in which travellers have an unreliable information system but a reliable route.

Note that in specific technical literature, several authors (Van der Mede and Van Berkum, 1996; Bogers et al, 2007; Ben-Elia et al., 2010) have modeled the effect of uncertainty on respondents’ behaviours by incorporating the variance over days of actual costs. According to this, in our paper we have modeled the risk perception by considering the variance of actual travel times of routes as input variable. For each input variable, statistical values have been calculated over different time intervals, according to experimental evaluations. These time intervals reflect the way in which human mind processes information through experience. For example, a respondent takes six days to perceive the effect of actual travel times' variance, while, he/she needs four days to evaluate the average value of actual travel time for each route.

### *5.2. Results*

Two kinds of analysis have been carried out: at first step, travellers’ choices and concordance (Table 6) have been calculated by the fuzzy inference system (FIS); at second step, the ability of FIS in reproducing the travellers’ behaviour (Table 7) in terms of concordance and route choice has been evaluated. With reference to the first step, a cross comparison among observed concordance, route preferences acquired by the experiment (Table 4), and results obtained by the fuzzy model (Table 7) has been carried out. In terms of concordance, FIS seems to overestimate the concordance in case of descriptive information, especially at more accurate levels. Instead, in case of prescriptive information, it seems to underestimate the concordance. In terms of route share, by comparing

Table 5 with Table 7, it is possible to observe that better results are obtained in scenarios with high accuracy levels. Results highlight that uncertainty embedded in human reasoning, especially when affected by inaccurate information, drives travellers to random choices. We can also observe that, for each scenario, the fuzzy model shows almost the same trend of travellers' route choice percentage. With reference to the descriptive information, a good value of concordance percentage is obtained for scenario 1. This scenario shows a high travellers' concordance, and the FIS reproduces correctly their behavior. For scenario 4, we observe a great uncertainty in travellers' choices, while the fuzzy model mainly chooses route 2, which is the most reliable. In this case, results are not so accurate as in case of prescriptive information.

Table 6: Choices of fuzzy inference system and concordance

| Type of Information | Accuracy | Route 1 % | Route 2 % | Route 3 % | Concordance % |
|---|---|---|---|---|---|
| Descriptive | High | 56.7 | 20.0 | 23.3 | 80.0 |
| | Intermediate 1 | 53.3 | 23.3 | 23.3 | 76.7 |
| | Intermediate 2 | 50.0 | 16.7 | 33.3 | 76.7 |
| | Low | 23.3 | 60.0 | 16.7 | 56.7 |
| | All scenarios | 46.4 | 29.3 | 24.4 | 72.9 |
| | Observed* | 43.1 | 39.2 | 26.0 | 57.8 |
| Prescriptive | High | 73.3 | 3.3 | 23.3 | 63.3 |
| | Intermediate 1 | 80.0 | 3.3 | 16.7 | 56.7 |
| | Intermediate 2 | 63.3 | 20.0 | 16.7 | 50.0 |
| | Low | 6.7 | 86.6 | 6.7 | 26.7 |
| | All scenarios | 55.8 | 28.3 | 15.8 | 49.2 |
| | Observed* | 40.9 | 33.2 | 25.9 | 58.5 |

*The "Observed" values are obtained from Table 4, as average over scenarios for each kind of information.

At the second step, the results have been also analyzed by calculating the %-right as the ability of FIS to reproduce the observations. With reference to Table 7, we can observe that scenarios 1, 2 and 3 reproduce correctly travellers' choices, while in scenario 4 the %-right is quite low (45.0%). The overall %-right reaches 55.4% that can be considered acceptable. As for prescriptive information, results can be considered less satisfying. %-right shows that in case of descriptive information, concordance is reproduced better than not-concordance.

In prescriptive information scenario, both concordance and not-concordance are reproduced in a satisfactory way. Results can be considered acceptable with reference to the column "Overall", in which %-right values are obtained combining results of concordant – concordant (C-C%) and not concordant –not concordant (NC-NC %) for each scenario/ all scenarios.

## 6. Conclusions and future work

According to technical literature, accurate information can have significant effects on travellers' choices. In this work, the effect of two different kinds of information with four levels of accuracy has been studied. Results show a significant effect of information inaccuracy on travellers' concordance and on route share: inaccuracy seems to affect route preferences if the context of choice is perceived as uncertain. In very accurate scenarios, concordance is high and travellers prefer the shortest route; instead, at the lowest accuracy level, respondents perceive the context of choice as uncertain (framing effect) and for this reason they prefer the most reliable route. At intermediate accuracy levels, travellers' behaviour is rather confused: concordance decreases with respect to high accuracy levels, even if observed routes' preferences are confused. At low accuracy level, choices seem to be randomly distributed among routes. Moreover, in order to consolidate the effect of uncertainty on respondents' choices, the variance over days of the actual travel times has been incorporated as input variable.

Table 7: %-right for route choices and concordance (Observed choices vs. predictions by FIS)

| Type of Information | Accuracy | % right | C-C % | C-NC % | NC-C % | NC-NC % | Overall |
|---|---|---|---|---|---|---|---|
| Descriptive | High | 65.2 | 84.9 | 15.1 | 69.2 | 30.8 | 67.9 |
| | Inter. 1 | 59.3 | 83.2 | 16.8 | 66.5 | 33.5 | 63.7 |
| | Inter. 2 | 51.0 | 82.8 | 17.2 | 69.6 | 30.3 | 58.3 |
| | Low | 45.0 | 61.8 | 38.2 | 51.9 | 48.1 | 54.6 |
| | All | 55.4 | 79.5 | 20.5 | 63.8 | 36.2 | 61.3 |
| Prescriptive | High | 50.5 | 85.0 | 15.0 | 41.3 | 58.7 | 71.9 |
| | Inter. 1 | 41.1 | 79.2 | 20.8 | 41.0 | 59.0 | 67.3 |
| | Inter. 2 | 42.0 | 72.9 | 27.1 | 33.4 | 66.6 | 69.2 |
| | Low | 48.4 | 33.0 | 67.0 | 20.8 | 79.2 | 56.8 |
| | All | 46.1 | 67.5 | 32.5 | 34.1 | 68.9 | 66.9 |

*C= concordant; NC = Not concordant

Moreover, in order to consolidate the effect of uncertainty on respondents' choices, the variance over days of the actual travel times has been incorporated as input variable. Fuzzy logic has been applied in order to reproduce travellers' concordance and route choices. The obtained results are encouraging about usefulness of the adopted approach. In future works, authors would like to improve input attributes and rules of the FIS in particular, by introducing different weights for attributes will be examined. Furthermore, these results, obtained by the fuzzy approach, will be compared with those obtained in previous researches by discrete choice modelling.

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